The Effect of Gravity upon the Movements and Aggregation of Euglena viridis, *Ehrb., and other Micro-organisms.*

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(Abstract.)

In the course of some experiments on the effect of various physical forces upon the movements of *Euglena viridis*, it was found that, when placed in the dark in shallow vessels or narrow tubes, a peculiar aggregation of these organisms takes place into network-like patterns or more or less well-defined circular groups. The aggregation is only visible when the Euglenæ are abundant, and is more regular and pronounced in a shallow vessel than in a deep one, especially if it is completely filled with the liquid containing the organisms, and sealed up so that the upper surface is not in contact with the air. If a narrow tube filled with water containing sufficient Euglenæ to give it a pronounced green colour is placed horizontally in the dark or in a weak light, the aggregation takes the form of a series of nearly equally spaced groups, like green bands, crossing the tube from one side to the other, and extending along its whole length.

Each group shows clearly two distinct regions, a central denser one consisting of cells moving downwards, and a lighter peripheral area consisting of cells moving more or less regularly upwards. There is, in fact, a constant cyclic movement downwards and upwards, which is kept up so long as the aggregation persists. Examination with a pocket lens shows that, as the organisms reach the bottom of the stream, they gradually separate from one another, and begin to move upwards. As they reach the upper surface, they are seen to be drawn towards the central denser region of the group, and again enter the downward stream.

This aggregation, with its regular cyclic movements, may persist for several days, until the Euglenæ die, in fact, provided they are kept in the dark or under red glass. In a good light the aggregation soon disappears, but reappears again in a few seconds when placed in the dark. So also, if the aggregation is caused to disappear by shaking the vessel in which the Euglenæ are contained, it reappears again immediately the disturbance has ceased.

The ease and rapidity with which the aggregation takes place appear to depend, among other things, upon the activity of the Euglenæ. Anything

which tends to inhibit this, and to cause sluggish movements, such as a very low temperature, may entirely prevent the aggregation; but so long as the slightest movement takes place in the organisms, an aggregation may be visible, although it may be very indistinct, and only recognisable as a delicate ripple-mark like effect.

The aggregation does not appear to be due to any marked extent, and probably not at all, to currents set up in the liquid either by heat or evaporation; and it appears not to be dependent upon the presence or absence of oxygen or carbon dioxide, except in so far as these may be necessary to maintain the motility of the organism.

The downward movement appears to be a purely mechanical one, dependent upon the specific gravity of the organism, and is not due to a stimulus which evokes a physiological response as in geotropism or geotaxis. The upward movement is, on the other hand, due partly to the activity of the organisms themselves, partly no doubt to the upward currents set up in the liquid by the friction of the downward moving stream. The upward movement of *Euglena* appears to be controlled, so far as the orientation of its elongate body is concerned, by the action of gravity. If not crowded together, the motile cells of *Euglena* may move in any direction in space, but if anything interferes with their movements the pull of gravity immediately causes them to take a more or less vertical position with the posterior end pointing downwards. This is due to the fact that the organism is heavier than water and that the posterior end is heavier than the anterior.

The network-like aggregations and groupings resemble very closely in many respects the cohesion figures which are formed, under certain conditions, when fine sediments of various kinds, such as precipitates of manganese dioxide, osmium dioxide, etc., are allowed to settle slowly in a liquid; and the conclusion has been arrived at that such aggregations are probably of the nature of cohesion figures, due to the action of gravity upon organisms massed together, combined with the vortical movements set up when the streaming movements begin to take place.

In addition to *Euglena viridis*, experiments were made with colourless forms of the same species, with *E. deses*, *Chlamydomonas*, *Volvox*, Bacteria (*Spirillum*), and one of the fresh-water Peridineæ, in all of which the phenomena were visible, but with considerable variation in the extent to which it was produced.

It is a remarkable fact that the movements of micro-organisms should be controlled in this purely mechanical fashion, but the advantage to those species which, like *Euglena*, are often found in a confined space in very large numbers must be very great, as by its means a constant circulation of them

through all parts of the liquid takes place, and they are prevented from accumulating in such dense masses as would be detrimental to their existence by interfering with their assimilatory or respiratory functions. It is possible also that some of the peculiar phenomena of plankton distribution may be explained in this way.

Some Investigations Dealing with the State of Aggregation of Matter.—Parts I–III.

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Part I.—*On the Action of Salts in Heterogeneous Systems, and on the Nature of the Globulins.*

A. General Theory and Results.

During the course of some investigations on the action of formaldehyde on the proteins, the observation was made that this aldehyde, when added to an aqueous solution of Witte's peptone, produces a precipitate, and that the reaction could be either partially or completely inhibited by the presence of neutral salts. This phenomenon was also noticed some years ago by T. Sollman,* who offered no satisfactory explanation of the facts. The more recent investigations of Sörensen† have shown that when formaldehyde reacts with amino-acids a methyleneimino-derivative is produced, which is readily hydrolysed in the presence of water, yielding the original amino-acid and formaldehyde. The reaction is therefore a reversible one, and can be represented by the general equation

$$(NH_2)R{\cdot}COOH + HCHO \rightleftarrows (CH{:}N)R{\cdot}COOH + H_2O.$$

The amino-acid is only completely converted into the methyleneimino-derivative in the presence of a large excess of formaldehyde, and the methyleneimino-acid thus produced is, in contrast to the amino-acid from which it was formed, so strongly acid that it can be titrated with caustic alkalis in the presence of phenolphthalein as indicator. These results are an

* 'American Journal of Physiology,' 1902, vol. 7, p. 220.

† 'Biochem. Zeitsch.,' 1907, vol. 7, p. 45.